

"TEST VS. SIMULATION"

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JUNE 27, 1990

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INTRODUCTION

OVERVIEW: SPACE VEHICLES REQUIRE
SIMULATION CAPABILITIES

PROPULSION
STRUCTURES
LOADS
AERODYNAMICS
CONTROL
OTHER

PRESENTATION SCOPE: PROPULSION SIMULATION AND PROPULSION SYSTEM TESTING

PRESENTATION OBJECTIVE/

APPROACH: THROUGH ASSESSMENT OF SIMULATION CAPABILITIES AND REVIEW OF
CONTRIBUTIONS FROM PROPULSION SYSTEM TEST PROGRAMS ILLUSTRATE
THAT BOTH SIMULATION AND PROPULSION SYSTEM TESTING EACH HAVE
IMPORTANT ROLES IN SPACE VEHICLE DEVELOPMENT.

SIMULATION CAPABILITY ASSESSMENT

(NO PROPULSION SYSTEM TEST)

EVALUATION CRITERIA	VEHICLE FLIGHT CATASTROPHE RISK	MISSION LOSS RISK	LAUNCH DELAY RISK	LAUNCH COMPLEX RISK	SYSTEM TEST PROVIDES DATA	REMAINING RISK AFTER 20 SECOND FRF
"Wrong" Component Verification	Very High	Very High	High	High	Yes	Low
Instrumentation Failure	Moderate	Moderate	Very High	Very High	Yes	Minor
Hazardous Fluid Leakage	High	High	Very High	Very High	Yes	Moderate
POGO Failure	Moderate	High	Minor	Minor	Can	Moderate
Thrust Vector Control Failure	Low	Low	Low	Minor	No	Minor
Propellant Loading Procedures/Operations	No	No	Very High	High	Yes	No benefit
Clustered Engine Performance	Minor	Minor	Minor	Minor	Yes	Minor
Performance Margin Uncertainty	Minor	High	No	No	Yes	Moderate
Stored Gas Mass, Loading, Operations	Minor	Minor	Minor	Moderate	Yes	Minor

SIMULATION CAPABILITY ASSESSMENT

(NO PROPULSION SYSTEM TEST)

EVALUATION CRITERIA	VEHICLE FLIGHT CATASTROPHE RISK	MISSION LOSS RISK	LAUNCH DELAY RISK	LAUNCH COMPLEX RISK	SYSTEM TEST PROVIDES DATA	REMAINING RISK AFTER 20 SECOND FRF
Pressurization System Performance	Moderate	High	Minor	Minor	*Yes	Moderate
Propellant Mass Uncertainty	Minor	Moderate	Very High	Minor	Yes	Low
Low Level Cutoff Sensor	Minor	Minor	Moderate	No	Yes	No benefit
Engine/Feed Systems Chill	Minor	Minor	High	Minor	*Yes	Minor
Tank Insulation	Minor	Minor	High	Minor	*Yes	Minor
Hardware Thermal Control	Minor	Minor	High	Moderate	*Yes	Minor

* Mission Dependent

ADVANCED VEHICLE SIMULATION CAPABILITY ASSESSMENT
(NO PROPULSION SYSTEM TEST)

EVALUATION CRITERIA	SHUTTLE	ADVANCED VEHICLE WITH SMALLER VOLUME, COMMON BULKHEAD	
	FLIGHT CATASTROPHIC/ LAUNCH DELAY RISK	ALTITUDE START	ORBITAL START
		RISK	RISK
Pressurization Systems Performance	Moderate/ Minor	Much Higher/ Same	Significantly Higher/Higher
Propellant Mass Uncertainty	Minor/ Extremely High	Higher/Same	Much Higher/Same
Engine/Feed System Chill	Minor/High	Higher/Same	Significantly Higher/Higher
Tank Insulation	Minor/High	Higher/Same	Much Higher/Same
Hardware Thermal Control	Minor/High	Higher/Same	Significantly Higher/Higher

Note: Risk relative to shuttle.

SYSTEMS TESTS IDENTIFIED EVENTS

STAGE	CATASTROPHE		UNWORKABLE		TOTAL PER STAGE
	FLIGHT	PREFLIGHT	FLIGHT	PREFLIGHT	
SHUTTLE	3	3	5	17	40
S-1C	4	0	3	3	13
S-II	2	0	8	8	21
S-IVB	8	0	6	3	20
S-I/IB	5	1	4	2	15
S-IV ^a	2	0	3	1	6

* Incomplete

** Includes Categories not included

EXAMPLE

SHUTTLE

SSME NOZZLE STERN HORN RUPTURE - H₂ DUMPED.
MARGINAL STABILITY CHARACTERISTICS - ET/ORBITER 17" O₂ DISCONNECT.

SAT V

F-1 ENGINE TO STAGE BOLTS STRUCTURAL FAILURES
S-II ENGINE THRUST CHAMBER CHILL FAULTY - ENGINE STALL POTENTIAL

MPTA TESTING EVALUATION

ATTEMPTED FIRINGS/ABORTS	INERTING PURGE USAGE	FIRE WATER USAGE (EXTERNAL)	ABORT SOURCE
21/9	5K - 12 System 30K - 3 System	6	Vehicle 2 Engine 8

SATURN V, IB, I TESTING EVALUATION

DEVELOPMENT STAGES					FLIGHT STAGES	
VEHICLE	TEST NUMBER	ABORTS	TEST INADVERTENTLY "CUT"	TEST STAGE DESTROYED	ACCEPTANCE TESTED	DESTROYED IN TEST
SIC "ALL SYSTEMS"	15	5	3		15	1
S-11 BATTLESHIP ALL SYSTEMS	54 9	29 6	1	1	15	
SIV B	21	-	-	1	27	1
SI/IB	23	6			22	

MPTA Hardware Replacement and Repair

MPTA Test Number	Pumps	Major Valves	ELU/MDMS	Other	LH ₂ Recirculation System, Pressurization System	Valves	Sensors	LH ₂ Diffuser, Feed Line Screens, Other
	← ENGINE →				← VEHICLE →			
1-002				1	4	5	4	1
2				1		1	1	2
3				1		1	1	2
4							1	1
5-A	12	9	1	1	4	2	4	3
5		9	1	1			4	
6-01		7	1	2	3		2	
6-02/3	1	7	1	5			5	1
6-04							4	
7-01		1			2			
7-02		2			5	1	4	
8		2						
9-01	1				1	1	2	
9-02	4		1		1			
10		4	10	3	1		2	
11-01	2	7		3	4	6	2	
11-02				3	6	4		
12				3		1		
Total	20	41	15	20	30	21	40	10

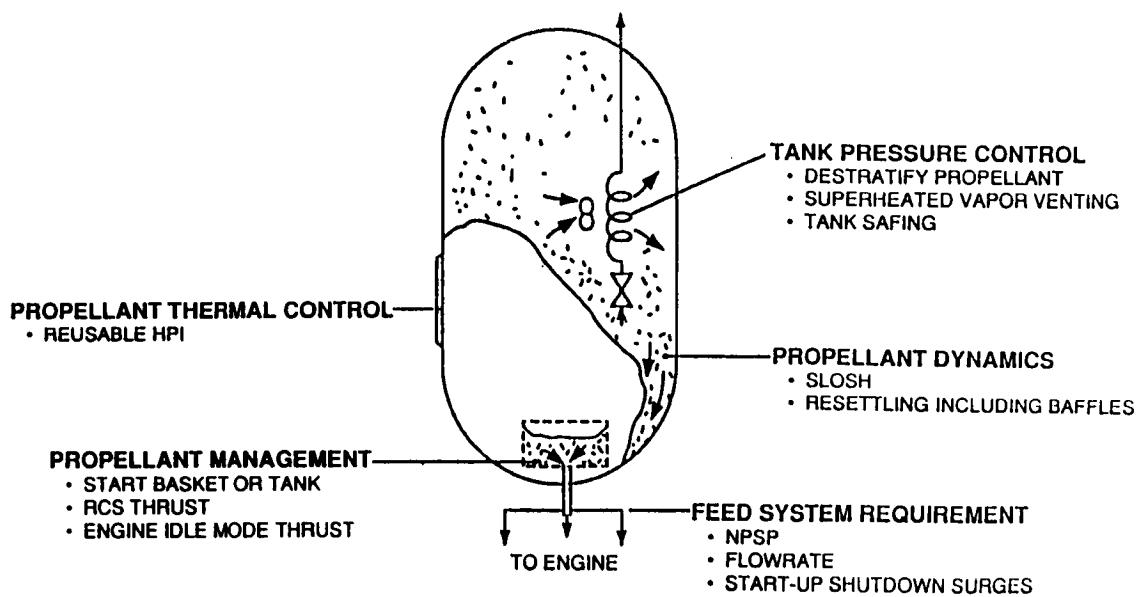
Note: Hardware changes made prior to designated test number

**"SPECIAL" VEHICLE SIMULATION ISSUES
(PROPULSION RELATED)**

SPACE ENVIRONMENT EFFECTS ON:

- PROPELLANT MANAGEMENT
- PROPELLANT THERMAL CONTROL
- TANK PRESSURE CONTROL
- PROPELLANT DYNAMICS
- PROPELLANT RESUPPLY

"SPECIAL" VEHICLE SIMULATION ISSUES



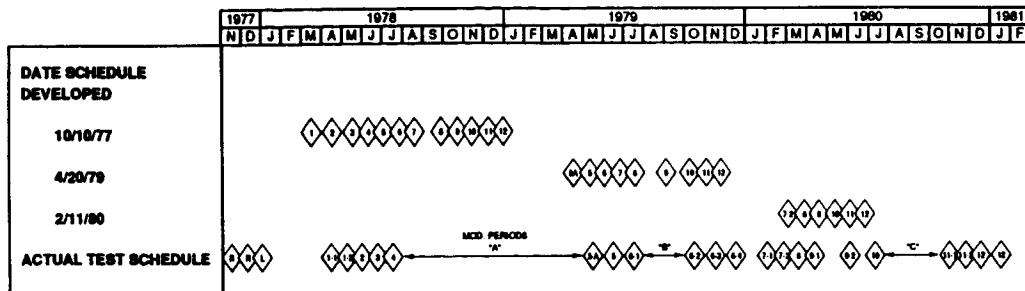
"SPECIAL" VEHICLE SIMULATION ISSUES (PROPULSION RELATED)

SIMULATION ASSESSMENT:

FOR SOME ISSUES -

- NECESSARY TECHNOLOGY DOES NOT EXIST
- DEMONSTRATION OF TECHNOLOGY NECESSARY
- ORBITAL EXPERIMENTAL DATA NECESSARY
- DEVELOPMENT STAGE GROUND TEST POSSIBLE/DESIRABLE
- SPECIAL DEVELOPMENT GROUND FACILITIES REQUIRED

MPTA TEST SCHEDULE



NOTE: R.L. - RESONANT/LOADING TESTS

CONCLUSIONS

- PROPULSION SYSTEM TESTING HAS PREVENTED CATASTROPHE AND MISSION LOSS EVENTS AND LAUNCH DELAYS.
- THE COMPLEXITY OF INTERACTIVE CHARACTERISTICS OF VARIOUS SUBSYSTEMS/DEFIES ACCURATE SIMULATION. SYSTEM TESTING PROVIDES FOR MODEL BASING AND ENHANCES SIMULATION.
- SOME ADVANCED/"SPECIAL" VEHICLES MAY HAVE EQUAL OR GREATER REQUIREMENTS FOR PROPULSION SYSTEM TESTING AND UNUSUAL TEST FACILITIES/METHODS MAY BE REQUIRED.
- A GROUND PROPULSION "SYSTEM TEST" PROGRAM IS THE LOGICAL APPROACH FOR PROVING DESIGN CHARACTERISTICS/METHODS WHERE FLIGHT CATASTROPHIC FAILURES OR OTHER FAILURES CAN BEST BE UNDERSTOOD AND CONTROLLED.
- ADVANCEMENT IN TECHNOLOGY AND TECHNOLOGY DEMONSTRATION IN SOME AREAS IS NECESSARY TO SATISFY FUTURE MISSION REQUIREMENTS.